



**CRANE CO.
Hydro-Aire Inc.
& Lear Romec
Submission to the
National Transport Safety Board
TWA Flight 800 Investigation
DCA96MA070**



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I Lear Romec Scavenge Pump

I.A Executive Summary

On July 17, 1996, at 2031 EDT, a Boeing 747-131, N93119, crashed into the Atlantic Ocean, about 8 miles south of East Moriches, New York, after taking off from John F. Kennedy International Airport (JFK). The airplane was being operated on an instrument flight rules (IFR) flight plan under the provisions of Title 14, Code of Federal Regulations (CFR), Part 121, on a regularly scheduled flight to Charles De Gaulle International Airport (CDG), Paris, France, as Trans World Airlines (TWA) Flight 800. The airplane was destroyed by explosion, fire, and impact forces with the ocean. All 230 people aboard were killed.

Crane Co. participated as a Party Member to the Investigation. A predecessor of Crane's Lear Romec Division manufactured the Center Wing Tank (CWT) scavenge pump on board TWA Flight 800. Hydro-Aire, Inc., a Crane Co. subsidiary, manufactured the Jettison/Override pumps installed on the aircraft. Pursuant to the provisions of 49 CFR Section 845.27, Crane Co.'s Submission to the Board is contained herein.

The investigation took place over a period in excess of three and one-half years. One area of emphasis was potential ignition sources leading to a CWT explosion. All critical portions of the CWT Scavenge System were recovered from the accident site, with the exception of the scavenge pump. All of the Jettison/Override pumps were recovered.

Presented within is Crane Co.'s assessment of critical portions of the Systems Group (Group) factual evaluation of the CWT Scavenge System.

As discussed below, Crane Co. believes that the CWT scavenge pump was not in operation at the time of the accident and that the probable cause of the CWT ignition was in a system other than the CWT Scavenge System.

Since all of the Jettison/Override pumps were recovered, inspected, and cleared as possible ignition sources, discussion of these components in this submission is limited.

I.B Scavenge Pump System Functional Description

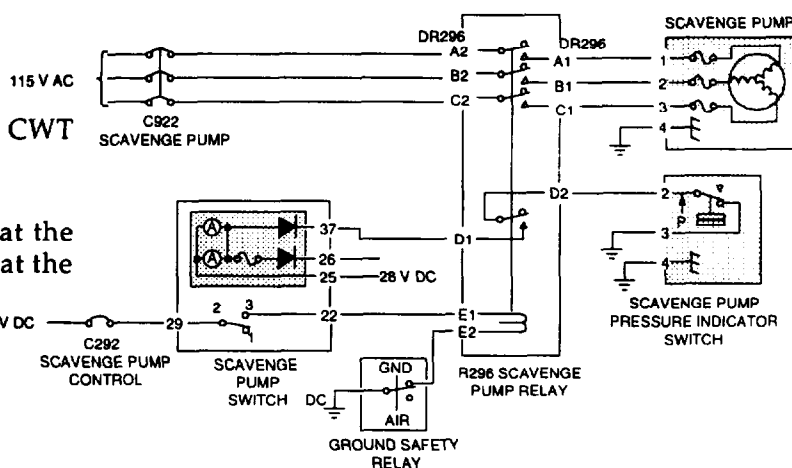
The scavenge pump is used to pump any remaining fuel out of the Center Wing Tank (CWT) once the level of fuel is below the pick ups of the other CWT pumps. Figure 1 illustrates the electrical schematic diagram for the scavenge pump system.

Operating power is supplied to the pump motor windings via the Scavenge Pump Relay (R296) which receives power from the 115 volt ac Scavenge Pump Circuit Breaker (C922).

The Scavenge Pump Relay uses 28 volt dc control power for operation. Control power is supplied to the relay operating coil via the Scavenge Pump Switch from the Scavenge Pump Control Power Circuit Breaker (C292). The control power circuit is then routed to electrical ground through the Ground Safety Relay. Normal operation of the scavenge pump occurs only when the aircraft is in the air and the Ground Safety Relay scavenge pump contacts are closed.

The scavenge pump low pressure indication circuit, including the low pressure indicating light, receives

Figure 1 CWT Scavenge Pump Electrical Schematic



28 volt dc power. Its electrical ground path is provided via the Scavenge Pump Relay and the Scavenge Pump Pressure Switch.

To operate the scavenge pump both the Scavenge Pump Circuit Breaker and the Scavenge Pump Control Power Circuit Breaker must be closed. The Scavenge Pump Switch is moved to the "ON" position (3) and 28 volt dc control power is supplied to the operating coil inside of the Scavenge Pump Relay (via E1/E2). Energizing the coil causes the scavenge pump motor power contacts (A2/A2, B1/B2, C1/C2) and the Scavenge Pump pressure indicating light contacts (D1/D2) inside of the Scavenge Pump Relay to close. Only then is 115 volt ac power supplied to motor for operation and 28 volt dc power is available for pressure indication. During normal pump operation the Scavenge Pump Pressure Indicator Switch contacts are open. If for any reason the pump stops pumping the Scavenge Pump Pressure Switch contacts close, illuminating the scavenge pump low pressure light on the Flight Engineer's panel.

I.C Scavenge Pump Factual Discussion & Analysis

The understanding that without power being supplied to the pump there is no way for the scavenge pump to provide a source of the CWT ignition is a basic premise in the examination of the scavenge pump's involvement in the TWA 800 accident. This is not, however, the sole basis for factual conclusions drawn in this submission. The following sections review the factual information developed during the investigation on a component basis and evaluate the relevance to the ability to supply power to the scavenge pump. No discussion of the actual scavenge pump involved in the TWA 800 accident is provided because the pump has not been recovered.

I.C.1 Scavenge Pump Switch

The Scavenge Pump Switch was recovered from the accident site and thoroughly examined. The factual report provides a discussion of the operation of the switch and cites the examination performed by the Materials Integrity Branch at Wright-Patterson Air

Force Base (TWA 800 Switch Analysis (Failure Analysis), WL/MLS 97-074). It concludes there is no evidence to indicate the switch was in the 'ON' position during the accident sequence¹ and that "evidence was found that the switch had been in the OFF position at time of recovery".²

Information presented in WL/MLS 97-04, when further considered, yields additional insight as to the position of the Scavenge Pump Switch at the time of the accident, namely contact surface condition and actuating lever (knob) witness marks.

The switch failure analysis states that inside the Scavenge Pump Switch the "Salt water-like residues and contamination on the contact surfaces of the switches indicate the contacts were received in the same position as they were recovered from the mishap site".³

Report WL/MLS 97-074 addresses the question of whether an impact to the scavenge pump switch knob, as evidenced by a gouge, resulted in a force toward the "OFF" direction.⁴ The conclusion drawn and evaluation presented in the factual report vector force diagram⁵ is based on the assumption that the impact between the knob and the striking object is a glancing collision, such as two pool balls striking each other. The gouge in the knob and associated displacement of metal is evidence that the switch was not forced toward the "OFF" direction. Consideration must be given to the direction and magnitude of the force to cause the gouge and the resultant reaction forces in the knob. **Figure 2** represents the force of the impact causing the gouge and shows the components of that force as related to switch operation. An estimated force of twelve pounds was required to cause the gouge. This results in approximately ten pounds of force in the "ON" direction and seven pounds of force along the toggle shaft preventing movement over the cam locking ring. Movement of the knob in the "ON" direction is blocked by the detent mechanism. Such an interaction also produces approximately a three pound force on the knob to the right while in the "OFF" position, consistent with the damage noted on the locking cam.⁶

Considering the above evaluation of the factual information, not only is there "... no evidence to

¹ Systems Group Chairman's Factual Report of Investigation, Docket No. SA-516, Exhibit No. 9A, p. 74.

² IBID, p. 69.

³ WL/MLS 97-074, Summary of Findings, p. 5.

⁴ Ibid, pp. 5-6.

⁵ Ibid, Figure 10, p. 13.

⁶ Ibid, Figures 12 & 13, p. 15.

⁷ Ibid, Summary of Findings, p. 6.

support any forced movement to the "off" position by impact or some other means from the mishap breakup⁸, there is also considerable evidence to indicate the Scavenge Pump Switch was in the "OFF" position at the time of the accident.

I.C.2 Low Pressure Indication Light

The Factual Report states that examination of the low pressure indicating light bulb filament revealed it was not stretched but broken.⁹ This indicates that at the time the filament broke, no power was being supplied to heat or illuminate the bulb.

For the low pressure indicating light to be illuminated, the following conditions must exist simultaneously: 28 volt dc power must be available, and the Scavenge Pump Relay must be energized with the low pressure indicating contacts closed, i.e. a low pressure rise condition across the pump must exist.

Evidence exists indicating both control power, 28 volt dc, and motor power, 115 volt ac were available to the scavenge pump system at the time of the accident. Given that "... numerous electrical powered devices stopped at about the same time", the flight data recorder (FDR) and cockpit voice recorder (CVR) ceased function within a quarter second of each other, and the final secondary radar returns were from approximately the same time¹⁰, compelling information exists to indicate that loss of electrical power was closely coupled in time with the CWT ignition, explosion, and breakup of the aircraft.

The fact that electrical power was available for the pump and the low pressure indicating light was not illuminated during the initial explosion and breakup is indication that either the scavenge pump was not on, or if it was on, it was pumping properly.

I.C.3 Scavenge Pump Relay

The Scavenge Pump Relay was recovered, examined, and "In summary, none of the contacts were

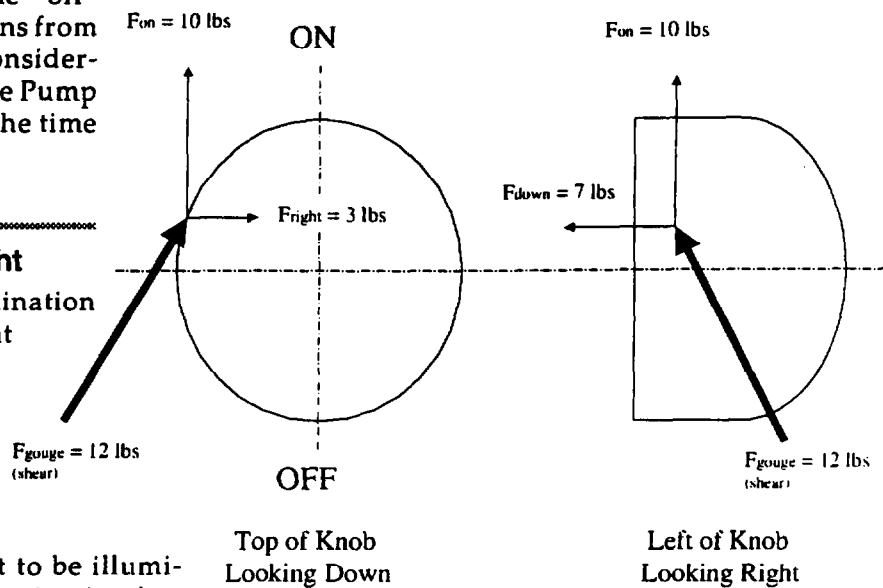


Figure 2 Gouge Force Diagram

found melted, eroded, or excessively worn and nothing was found outside of normal wear for that age of relay."¹⁰ A detailed examination and analysis was conducted by Materials Integrity Branch at Wright-Patterson Air Force Base and is documented by Scavenge Pump Relay (Failure Analysis), WL/MLS 97-078.

Crane Co. concurs with this analysis and notes no evidence of improper Scavenge Pump Relay operation.

I.C.4 Scavenge Pump Control Power Circuit Breaker

The Scavenge Pump Control Power Circuit Breaker (C292) was recovered and examined. The detailed examination and analysis was conducted by Materials Integrity Branch at Wright-Patterson Air Force Base and is documented by TWA 800 R296 Scavenge Pump Relay and Reserve Transfer Valve Circuit Breakers (Failure Analysis), WL/MLS 97-086.

The examinations indicate that the Scavenge Pump Control Power Circuit Breaker exhibited no signs of arc erosion on the contacts¹¹ and remained set

⁸ Systems Group Chairman's Factual Report of Investigation, Docket No. SA-516, Exhibit No. 9A, p. 69.

⁹ Ibid, p. 6.

¹⁰ Ibid, p. 74.

¹¹ WL/MLS 97-086, p. 4.

¹² Systems Group Chairman's Factual Report of Investigation, Docket No. SA-516, Exhibit No. 9A, p. 69.

through the accident and recovery¹².

Crane Co. concurs with this analysis and notes no evidence of improper Scavenge Pump Control Power Circuit Breaker operation.

I.C.5 Scavenge Pump Circuit Breaker

The Scavenge Pump (motor windings) Circuit Breaker (C922) was recovered. Although a detailed report was not complete at the time of the initial Factual Report publication, a detailed examination and analysis was conducted by Materials Integrity Branch at Wright-Patterson Air Force Base. It is documented by Analysis of Scavenge Pump Three Phase Circuit Breaker (Failure Analysis), WL/MLS 98-013.

The examination of all 12 mating contacts revealed no evidence of deep pitting from melting or abnormal wear on any of the mating surfaces.¹³ Additionally, there was no evidence of thermal damage, discoloration, or arcing on the circuit breaker.¹⁴

Crane Co. concurs with this analysis and notes no evidence of improper Scavenge Pump Circuit Breaker operation.

I.C.6 Operations Under Theoretical Scavenge Pump Failure Scenarios

The previous sections deal primarily with system operations under normal conditions. Situations in which single and multiple faults occur that lead to the possibility of the scavenge pump running without the Scavenge Pump Switch being in the "ON" position were also evaluated. Boeing conducted an electrical failure analysis. A summary of the results were documented in a 20 January 1999 letter to the NTSB, B-B600-16593-ASI, Subject: Scavenge Pump Circuit, TWA 747-100, N93119 Accident off Long Island, NY - 17 July 1996.

Boeing's study evaluated potential faults throughout the entire scavenge pump system. It identified 79 potential faults, only 4 of which could lead to the potential of the scavenge pump running when the switch is not in the "ON" position. Three of the four potential scenarios were ruled out based on exami-

nation of the actual components involved and considering single failure criteria. The fourth potential scenario (and a variation of the third scenario) requires multiple wiring insulation failure occurring in exactly the same location to provide power to the component in question. Boeing states "This scenario is also considered extremely unlikely because of the unique set of multiple, each highly improbable, failures that would have to occur simultaneously".¹⁵

Field service history is consistent with this evaluation. "An extensive records search of Boeing and airline service history did not turn up any report of a scavenge pump running when the switch was in the "OFF" position on a 747 classic airplane."¹⁶

Boeing states "The evidence, while not absolutely conclusive, indicated that the system was in normal working condition, switched off and indeed not powered".¹⁷

Crane Co. concurs with this analysis and evaluation.

I.C.7 Scavenge Pump Inlet Tube Condition

A fragment of tubing was recovered from the accident and identified as a portion of the scavenge pump inlet tube. The inlet tube provides a suction path between the pump inlet and the bottom of the CWT.

Examination of the inside of the tube revealed "No evidence of sooting or flow patterns were found".¹⁸

Crane Co. concurs with this analysis.

I.C.8 Scavenge Pump Qualification and Service History Issues

During the investigation close scrutiny was given to actual field pumps and conditions found within those pumps. Two components inside of the scavenge pump were identified as requiring a more in-depth evaluation of field findings, the motor cooling tube and the electrical connector. The following sections examine the relevant qualification history,

¹³ WL/MLS 98-013, p. 3.

¹⁴ Ibid, p. 4.

¹⁵ Boeing letter to NTSB, B-B600-16593-ASI, p. 2.

¹⁶ Ibid, p. 3.

¹⁷ Ibid.

¹⁸ Systems Group Chairman's Factual Report of Investigation, Docket No. SA-516, Exhibit No. 9A, p 73

review the factual information developed during the investigation, and evaluate the relevance of each issue to the TWA 800 accident investigation.

I.C.8.i Scavenge Pump Qualification

During the investigation, the Aircraft Systems Group reviewed the scavenge pump qualification history. Both the thermal design and the explosion proof characteristics were examined.

"The review found that the pump passed hours of qualification tests in which it had been operated without cooling fuel and the end of each test came when the thermal fuse had opened."¹⁹ In addition to the above "Dry Run" test, a Thermal Protection test was conducted in which the pump was operated dry, without cooling or lubricating fuel, and with intentionally distorted bearings. The pump was operated until the thermal fuses opened. In all tests the thermal fuses opened and stopped the operation of the pump prior to the surfaces reaching 400 degrees Fahrenheit.

"The review also found the scavenge pump successfully completed explosion proof testing by: (1) never causing an explosion in an explosive atmosphere, and (2) by containing multiple explosions intentionally set-off within the motor and preventing it from propagating to a surrounding explosive atmosphere."²⁰ Additionally Boeing concurred in that "... the Lear Romec scavenge pump meets all of the design requirements for being explosion proof."²¹

The Lear Romec Scavenge Pump meets the thermal design and explosion proof design requirements.

I.C.8.ii Cooling Tube Service Issue

A small diameter cooling tube is located inside of the explosion proof motor chamber. The purpose of the tube is to direct the fuel circulating flow to the end of the motor cavity. Some units returned from the field were missing the cooling tube or the cooling tube was in the motor but broken. Those units exhibited indication that the pump was improperly disassembled in the field. These findings gave rise to the desire to further evaluate the continued explosion proof capability of the scavenge pump with the cooling tube missing.

Figur

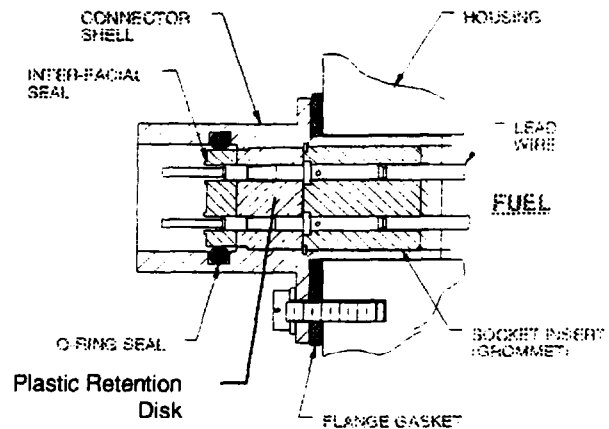


Figure 3 Electrical Connector Cross Section

"Since the group became aware of instances in which the cooling tubes had been broken or missing, a series of tests were conducted in October 1997, to determine whether the pump motor housing would continue to contain explosions with only the check valve. Samples of a new pump and one from service were tested. In each case, the explosions were contained in the housings and the explosive atmosphere surrounding the test pumps did not ignite."²²

Crane Co. concurs with the evaluation. The cooling tube service issue was not a factor in the accident.

I.C.8.iii Electrical Connector Grommet Material Issue

During the investigation it was found that some scavenge pumps had electrical connectors installed during non-factory overhauls, that were made with an unqualified socket insert (grommet) material which can degrade with long-term fuel exposure. These findings gave rise to the desire to further evaluate the continued explosion proof capability of the scavenge pump and its leak tightness with the incorrect grommet material installed.

All Lear Romec production and service units installed connectors with the correct grommet material.

During the same group activity discussed above, in October 1997, a connector with the incorrect, de-

¹⁹ Ibid, p. 70.

²⁰ Ibid.,

²¹ Boeing letter to NTSB, B-B600-16593-ASI, p3

²² Systems Group Chairman's Factual Report of Investigation, Docket No. SA-516, Exhibit No. 9A, p. 70.Ibid

graded material was found in the scavenge pump obtained from an airline. After the tear-down inspection of the unit it was modified to incorporate a spark plug for the explosion proof testing, reassembled, and leak tested. The degraded connector passed the external leakage test. The Group conducted the explosion proof testing with the service unit that contained the degraded grommet material. The explosion was contained in the housing and the explosive atmosphere surrounding the test pump did not ignite.²³

In addition to the testing, "The [Group] design review found that the scavenge pump connector pins were held apart by a plastic contact retention disk and that if a fire were ignited by a short circuit at the connector, it would have to pass through the flame arrestor tubes and the check valve to reach the fuel tank. The wheel well also had been equipped with heat detectors. Soot and fire patterns were not found to emanate from the rear wing spar at the fuel pump mounting hole."²⁴

Crane Co. concurs with the evaluation. The connector grommet material issue was not a factor in the accident.

I.D Summary Conclusion on Scavenge Pump

The Aircraft Systems Group conducted an extremely thorough investigation of the CWT Scavenge System components recovered from the accident site. The opening paragraph in the CWT Scavenge System states "No evidence was found that the scavenge pump in the accident airplane had been powered at the time of the accident."²⁵ The report provides detailed information regarding the evaluation of each component inspected. No evidence was discovered of a component malfunction that could have caused the scavenge pump to be powered at the time of the accident. Crane Co. concurs with these observations and conclusions.

Examination of the total amount of CWT Scavenge System factual data gathered and further consideration of specific details provide a clear indication that the scavenge pump was not powered at the time of the accident.

Furthermore, the investigation established the scavenge pump meets all explosion proof requirements, include situations in which the pump is not in its qualified configuration.

For these reasons, Crane Co. believes that the probable cause of the CWT ignition is within a system other than the CWT Scavenge system.

²³ Group Activity Field Notes, October 30, 1997.

²⁴ Systems Group Chairman's Factual Report of Investigation, Docket No. SA-516, Exhibit No. 9A, p. 70.

²⁵ Ibid, p. 69.

Reference Summary Table

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| ¹ Systems Group Chairman's Factual Report of Investigation, Docket No. SA-516, Exhibit 9A, p. 74. | ¹⁴ Ibid, p. 4. |
| ² IBID, p. 69. | ¹⁵ Boeing letter to NTSB, B-B600-16593-ASI, p. 2. |
| ³ WL/MLS 97-074, Summary of Findings, p. 5. | ¹⁶ Ibid, p. 3. |
| ⁴ Ibid, pp. 5-6. | ¹⁷ Ibid. |
| ⁵ Ibid, Figure 10, p. 13. | ¹⁸ Systems Group Chairman's Factual Report of Investigation, Docket No. SA-516, Exhibit No. 9A, p 73 |
| ⁶ Ibid, Figures 12 & 13, p. 15. | ¹⁹ Ibid, p. 70. |
| ⁷ Ibid, Summary of Findings, p. 6. | ²⁰ Ibid., |
| ⁸ Systems Group Chairman's Factual Report of Investigation, Docket No. SA-516, Exhibit No. 9A, p. 69. | ²¹ Boeing letter to NTSB, B-B600-16593-ASI, p3 |
| ⁹ Ibid, p. 6. | ²² Systems Group Chairman's Factual Report of Investigation, Docket No. SA-516, Exhibit No. 9A, p. 70.Ibid |
| ¹⁰ Ibid, p. 74. | ²³ Group Activity Field Notes, October 30, 1997. |
| ¹¹ WL/MLS 97-086, p. 4. | ²⁴ Systems Group Chairman's Factual Report of Investigation, Docket No. SA-516, Exhibit No. 9A, p. 70. |
| ¹² Systems Group Chairman's Factual Report of Investigation, Docket No. SA-516, Exhibit 9A, p. 69. | ²⁵ Ibid, p. 69. |
| ¹³ WL/MLS 98-013, p. 3. | |

II Hydro-Aire Jettison/Override Pumps

II.A Executive Summary

The two Hydro-Aire manufactured Jettison/Override pumps installed in the accident aircraft Center Wing Tank (CWT) were recovered and fully evaluated. Their appearance was clean, with no evidence of fire damage, arcing or heat exposure, and no evidence of stator winding discoloration. In addition, the recovered Flight Engineer's panel revealed that the switches for the CWT Jettison/Override pumps were in the OFF position. Evaluation of the Cockpit Voice Recorder (CVR) tape did not reveal any indication that the flight crew intended to return to the airport, and no indication that the CWT Jettison/Override pumps were operated during the flight. With an empty CWT (less than 100 gallons), there would have been no reason to operate that tank's Jettison/Override pumps.

The TWA Service Records for the Jettison/Override pumps indicated that they had all been recently serviced (at the TWA Kansas City overhaul base) between May, 1994 and March, 1996. Further, no evidence of any pump service related problems were found on any of the recovered units.

II.B Jettison/Override Pumps Functional Description

A total of fourteen Hydro-Aire Boost and Jettison/Override Fuel Pumps were installed on the 747-131 aircraft serial number N93119 being operated as TWA Flight 800. All of the pumps were a cartridge configuration; an outer housing located in the aircraft fuel tank and a removable motor-impeller assembly. A typical Outer Housing is illustrated in **Figure II-1**, and a typical Motor-Impeller unit illustrated in **Figure II-2**.

Boost pumps "boost" fuel to the engines to maintain fuel pressure to the engine driven fuel pumps. The primary function of the Jettison/Override pumps is to jettison fuel overboard in order to rapidly reduce aircraft landing weight in an emergency. Additionally, at the discretion of the Flight Engineer, the Jettison/Override pumps may be used for fuel management, to transfer fuel between tanks (for example to maintain aircraft balance).

Of the fourteen installed pumps, eight were Boost Pumps (two for each of the four engines) and the remaining six were Jettison/Override pumps. Two Jettison/Override pumps were located in the left and right inboard Main Wing Tanks (Main Wing Tank #2 and Main Wing Tank #3), and two were located in the Center Wing Tank. The Center Wing Tank (CWT) was empty (less than 100 gallons) for the flight.

The Jettison/Override fuel pump Outer Housing is located and permanently attached to the fuel tank

Figure II-1 Typical Pump Outer Housing

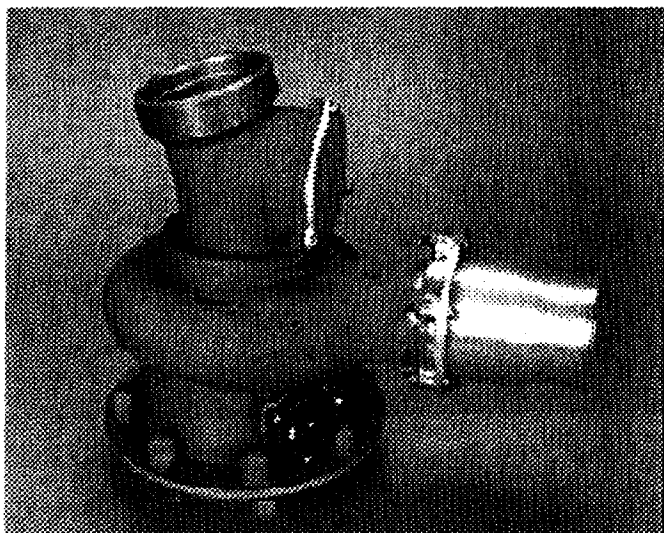
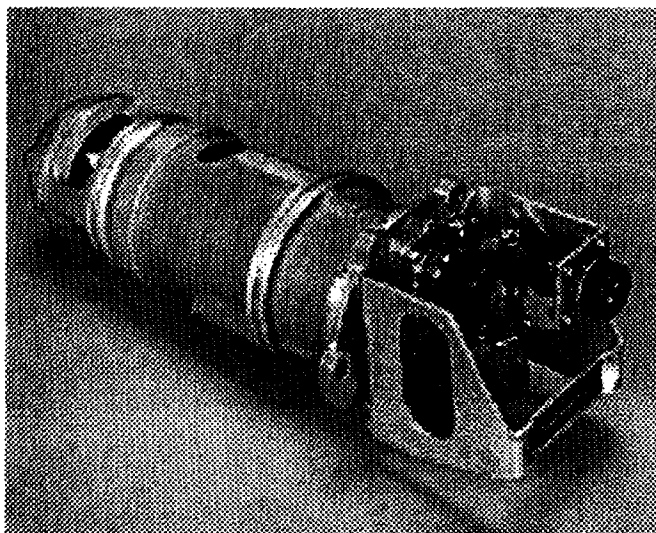


Figure II-2 Typical Motor-Impeller





rear bulkhead and provides the primary mechanical interfaces to the fuel tank; the inlet tube and connection to the fuel cross-feed lines. An internal Inlet Check Valve closes when the Motor-Impeller is withdrawn from the Outer Housing to prevent fuel leakage. The removable Motor-Impeller unit forms an explosion proof container housing the fuel cooled and lubricated pump electric motor. The pump impeller is located on the motor drive shaft which exits the explosion proof container to provide mechanical drive to the impeller. All electrical connections are located on the pump end-cap, external to the fuel tank.

II.C Jettison/Override and Fuel Boost Pumps Tear-down Inspection

Nine Hydro-Aire Jettison/Override and Fuel Boost Pumps were recovered from N93119 by salvage operations and subjected to a complete evaluation at the NASA facilities in Huntsville, Alabama. Importantly, the two CWT Jettison/Override Pumps (Outer Housing P/N 60-70305, Motor-Impeller P/N 60-703104) were among those evaluated.

II.C.1 Left CWT Jettison/Override Pump

Outer Housing S/N 0271200, Motor-Impeller S/N Not Known. A summary of the teardown inspection follows:

The end-cap was broken off and the stator windings were exposed and crushed. The end of the rotor shaft was missing. The outer housing had two holes and the flange missing. The inlet pipe check valve was in the up (open) position and the inlet pipe was missing. The jettison transfer butterfly valve was partly open

When cut open, the general condition was clean – there was no evidence of fire damage, arcing or heat exposure. The impeller and adapter showed only a small amount of slight contact. The bearings looked normal. There was no thermal discoloring evident on the stator windings. The priming impeller discharge plate was lightly scored and the inlet plate was clean.

II.C.2 Right CWT Jettison/Override Pump

Outer Housing S/N 2712017, Motor-Impeller S/N 10690394. A summary of the teardown inspection follows:

A CAT Scan was performed. There was electrical continuity between all three stator phases, indicating that the thermal fuses (internal type) had not melted.

When the pump was cut open, the general condition was clean, with no evidence of fire damage, arcing or heat exposure. There was no discoloration of the stator windings, as would have been expected if the pump overheated. The flame arrestor inside the shaft was intact.

II.D Summary Conclusion on Hydro-Aire Jettison/Override Pumps

The two Hydro-Aire manufacture Jettison/Override pumps from the Center Wing Tank (CWT) of the 747-131 aircraft, S/N N93119, operated as TWA Flight 800, together with seven other pumps, were recovered and fully evaluated. The internal appearance of the CWT Jettison/Override pumps was clean, with no evidence of fire damage, arcing or heat exposure, and no evidence of stator winding discoloration. In addition, the recovered Flight Engineers panel revealed that the switches for the CWT Jettison/Override pumps were in the OFF position. Evaluation of the Cockpit Voice Recorder (CVR) tape did not reveal any indication that the flight crew intended to return to the airport and contained no indication that the CWT Jettison/Override pumps were operated during the flight. With an empty CWT (less than 100 gallons), there would have been no reason to operate the Jettison/Override pumps.

The TWA Service Records for the Jettison/Override pumps indicated that they had been serviced at the TWA Kansas City overhaul base between May, 1994 and March, 1996. Further, no evidence of any service related problems were found on any of the recovered units.